Northeastern Forest Experiment Station
FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 102 MOTORS AVENUE, UPPER DARBY PA

ARTIFICIAL LIGHT SOURCES DIFFER IN EFFECT ON BIRCH SEEDLING GROWTH

The use of artificial lights to grow tree seedlings for research and even for commercial uses is becoming common. With this has come an increasing awareness that not all types of artificial lights produce the same results (2, 3, 5). The presence or absence of particular wavelengths in the light source may cause large differences in height growth and morphological development that are separate from the effects of light intensity.

Fluorescent lamps, although good for relatively high-intensity, uniformly-distributed light with a minimum of heat, are usually deficient in one or more of the important wavelength bands. Their output in the far-red band is extremely low, and the different types of lamps vary greatly in spectral distribution in the visible region. In most facilities for growing plants under artificial light, some type of fluorescent lamp is used as the primary light source, and incandescent bulbs are added to provide the far-red component.

In recent years, fluorescent tubes designed specifically for plant growth have appeared on the market. The output of these tubes is highest in the red and blue regions, which are the regions of greatest absorption by chlorophyll. They were designed to produce maximum photosynthesis and to enhance vegetative and reproductive growth in general. The assumption is often made that plants grown under these special fluorescent tubes will not require supplemental incandescent energy.

While setting up a light facility for growth of yellow and paper birch seedlings, the question naturally arose as to which of the many available light sources would produce best results. A simple experiment was therefore set up to test three different flourescent tubes, both with and without an incandescent supplement.

Study Methods and Materials

Six light compartments were constructed, using banks of six 8-foot fluorescent tubes in each compartment. Light baffles on the sides of each compartment permitted air flow through the compartment while restricting stray light. The three kinds of tubes used were the cool-white type, the warm-white type, and the tubes especially designed for plant growth, which bear the trade name Gro-lux.[1]

For each tube type two compartments were set up, one illuminated with fluorescent lamps alone, and one with three 25-watt incandescent bulbs in addition. Yellow birch and paper birch seedlings were grown from seed in Hoaglands No. 2 nutrient solution in a sand-vermiculite supporting medium. There were 3 seedlings in each pot, and 8 pots of each species for each treatment. Photoperiod was 20 hours. After 3 months' growth, seedling height, dry weight of roots, and dry weight of tops were determined. The analysis of variance was used for tests of significance.

Light-intensity measurements were taken under the various sources with a Model 501-M photometer with type-D phototube (Photovolt Corp.), filtered to limit the instrument's response to the visible region of the spectrum. Although the response of this phototube is not exactly equal at all wavelengths, it is nearly so, and is satisfactory for comparisons between treatments. The measurements revealed only minor differences in total visible energy emission by the three types of fluorescent tubes. For purposes of this study, their output is considered equal. It would be equivalent to about 800 foot-candles if measured under the cool-white tubes with a conventional illumination meter (such as Weston Model 756). The incandescent supplemental illumination increased energy emission in the visible region by an average factor of 1.25.

The relative spectral distribution of the three fluorescent tubes is shown below (adapted from Bulletins 0-205 and 0-236, Sylvania Lighting Products), in percent of total emission:

	Wavelength in millimicrons		
	380-490 *Violet & blue*	*490-590* *Green & yellow*	*590-700* *Red & orange*
Gro-lux	37.0	15.6	46.0
Warm white	18.3	44.1	36.0
Cool white	28.6	43.3	26.4

[1] All tubes were manufactured by Sylvania Lighting Products. Mention of particular commercial products should not be considered as endorsement by the U.S. Department of Agriculture or the Forest Service.

Results

Supplemental incandescent illumination resulted in significantly greater height growth (0.01-level) and top dry weight (0.05-level) with all fluorescent tubes (table 1 and fig. 1), but it did not significantly affect root dry weight. Seedling height and root dry weight differed under the three types of fluorescent tubes (0.05-level of significance) as follows:

- Yellow birch height was less under Gro-lux tubes than under the warm white or cool white fluorescents, both with and without the incandescent supplement.
- Paper birch root dry weight was lower under warm white fluorescents than under the other tube types, both with and without the incandescent supplement.
- Yellow birch root dry weight was lower under warm white fluorescents in the absence of supplemental incandescent illumination; with the incandescent supplement, the differences were not significant.

Part of the increased growth that occurred under incandescent supplemental illumination probably was due to the higher light intensity. Although the light measurements that were taken were not adequate for accurate evaluations of this effect, a simple calculation will permit rough

Table 1.—Average seedling heights and dry weights under various light sources

Species and tube type	Height[1]		Top dry weight[1]		Root dry weight[1]	
	0	+	0	+	0	+
	Inches		*Grams*		*Grams*	
Paper birch:						
Gro-lux	4.1	5.8	0.48	0.63	0.37	0.34
Warm white	4.2	6.2	.39	.56	.20	.26
Cool white	4.0	6.9	.55	.68	.37	.44
All tubes	4.1	6.3	.48	.63	.31	.35
Yellow birch:						
Gro-lux	2.8	4.5	.30	.37	.23	.21
Warm white	5.1	8.0	.35	.60	.14	.25
Cool white	3.7	7.2	.28	.63	.21	.37
All tubes	3.8	6.6	.31	.54	.20	.28

[1] 0 and + signs denote without and with supplemental incandescent illumination, respectively.

comparisons. The growth figures obtained with no incandescent supplement were raised by a factor of 1.25 — the amount of additional illumination obtained from the incandescents (table 2). This adjustment theoretically eliminates light intensity as a factor; growth differences remaining should therefore be due either to differences in the spectral distribution of the light sources or to experimental error. The adjustment is based on the assumption that growth is proportional to light intensity over the range between the compensation point and the saturation point. Although growth rates vary with species, light source, and other factors, the assumption of a nearly proportional increase with light intensity appears commonly in the literature; it is especially well supported by curves of growth over light intensity such as those of Dunn and Went (4) for tomato.

Although statistical tests of these crude estimates are not appropriate, the figures in table 2 suggest that the incandescent illumination itself, apart from intensity effects, accounted for much of the increased height growth that occurred in both species under the incandescent supplement. The independent effect of incandescent illumination on dry weight was less pronounced. It may have been an important factor in the greater top dry weight in yellow birch. The other dry-weight categories show little evidence of such an effect.

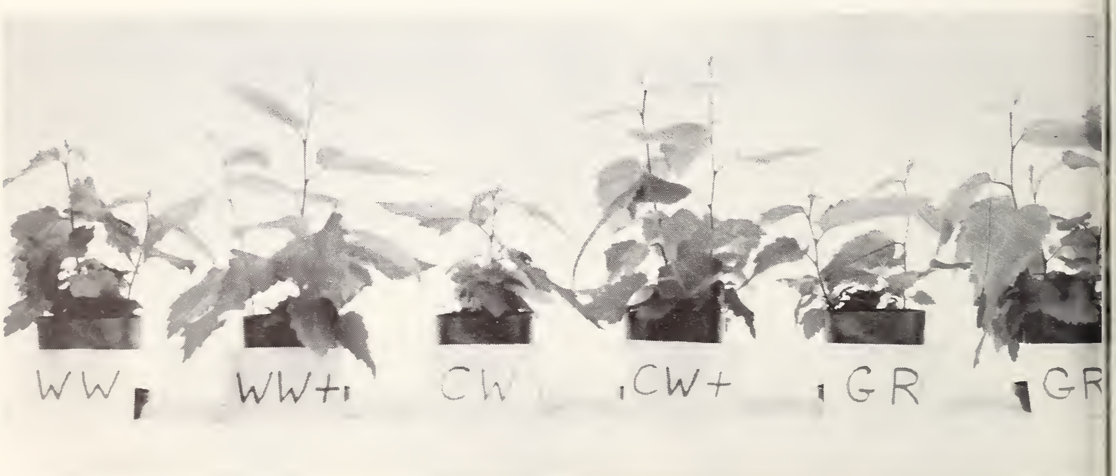

Figure 1.—Paper birch seedlings grown under 6 artificial light sources. From left to right: warm white fluorescents; warm white fluorescents plus incandescents; cool white fluorescents; cool white fluorescents plus incandescents; Gro-lux fluorescents; Gro-lux fluorescents plus incandescents.

Table 2.—Average seedling heights and dry weights adjusted to represent equal light intensities[1]

Species	Height[2]		Top dry weight[2]		Root dry weight[2]	
	0	+	0	+	0	+
	Inches		*Grams*		*Grams*	
Paper birch	5.1	6.3	0.60	0.63	0.39	0.35
Yellow birch	4.8	6.6	.39	.54	.25	.28

[1] Averages shown in table 1 for treatments without the incandescent supplement were raised by a factor of 1.25.
[2] 0 and + signs denote without and with supplemental incandescent illumination, respectively.

Discussion

The special fluorescent tubes (Gro-lux) did not produce better growth of birch seedlings than the other tubes in spite of their high energy output in the regions of maximum chlorophyll absorption. Presumably yellow-green light is utilized in photosynthesis by birch seedlings to a much greater extent than is suggested by the spectral absorption characteristics of chlorophyll. This is known to occur in some plants and is believed to be due to absorption and transfer of light energy to chlorophyll by other pigments (5).

Height growth was actually inhibited under the Gro-lux tubes. Seedlings under these lights were shorter, but possibly stockier, than those under the other tubes. Supplemental incandescent light was more essential for height growth with the Gro-lux tubes than with the others. This seems logical in view of the interacting and compensating effects of the red and far-red portions of the spectrum, which regulate shoot elongation in many plants; shoot elongation is promoted by far-red radiation and inhibited by red radiation (1). Hence, the greater height growth with incandescents is due to their relatively high output of far-red radiation, as compared to the fluorescents. Gro-lux tubes, because of their high output of red light, would tend to inhibit stem elongation more than the others. Even with incandescent supplemental illumination, the ratio of far-red to red would be lower under the Gro-lux tubes.

The effect of incandescent lights on dry matter production is not entirely clear. Theoretically, the far-red radiation obtained from incandescent bulbs should have little or no effect on the amount of photosynthate produced; it should simply alter the way in which this photosynthate is

distributed; i.e., it should determine whether the seedlings will be tall and spindly or short and stocky. Paper birch followed this theoretical pattern with increased height but normal dry weight when given supplemental incandescent illumination. Yellow birch, however, increased in both height and shoot dry weight with the incandescent supplement. Reasons for this are not apparent, but similar dry-weight increases resulting from incandescent bulbs also have been reported elsewhere (4).

For use in a plant growth facility, cool-white fluorescents with an incandescent supplement seem best for growing seedlings of yellow and paper birch. The more expensive Gro-lux bulbs, although perhaps having advantages for other species or for other purposes, were less satisfactory for our needs.

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— DAVID A. MARQUIS

Research Forester
Northeastern Forest Experiment Station
Forest Service, U.S. Dept. Agriculture
Laconia, N.H.